Critical thinking question:

http://www.cnn.com/2017/07/12/us/weather-cities-inundated-climate-change/index.html

What’s your reaction to this report?

ATOC 4800
Policy Implications of Climate
ATOC 5000/ENVS 5830
Critical Issues in Climate and the Environment

Lecture 2:

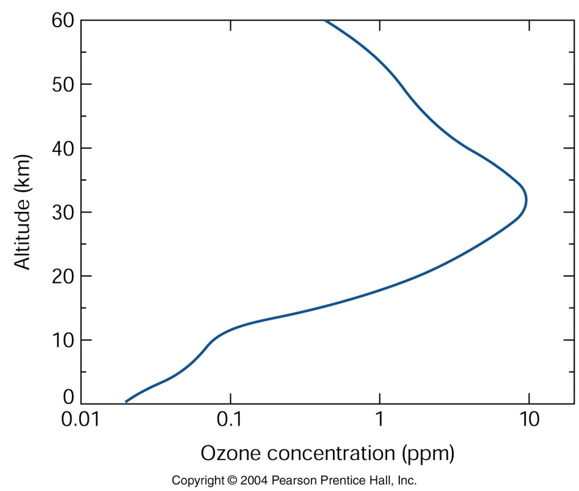
1. **Global warming: a range of observational evidence;**
2. **Attribution (global climate models) & future projection (IPCC AR5 WG I);**
3. **Impacts & policy implications: Adaptation & Mitigation (IPCC AR5 WG II & III)**

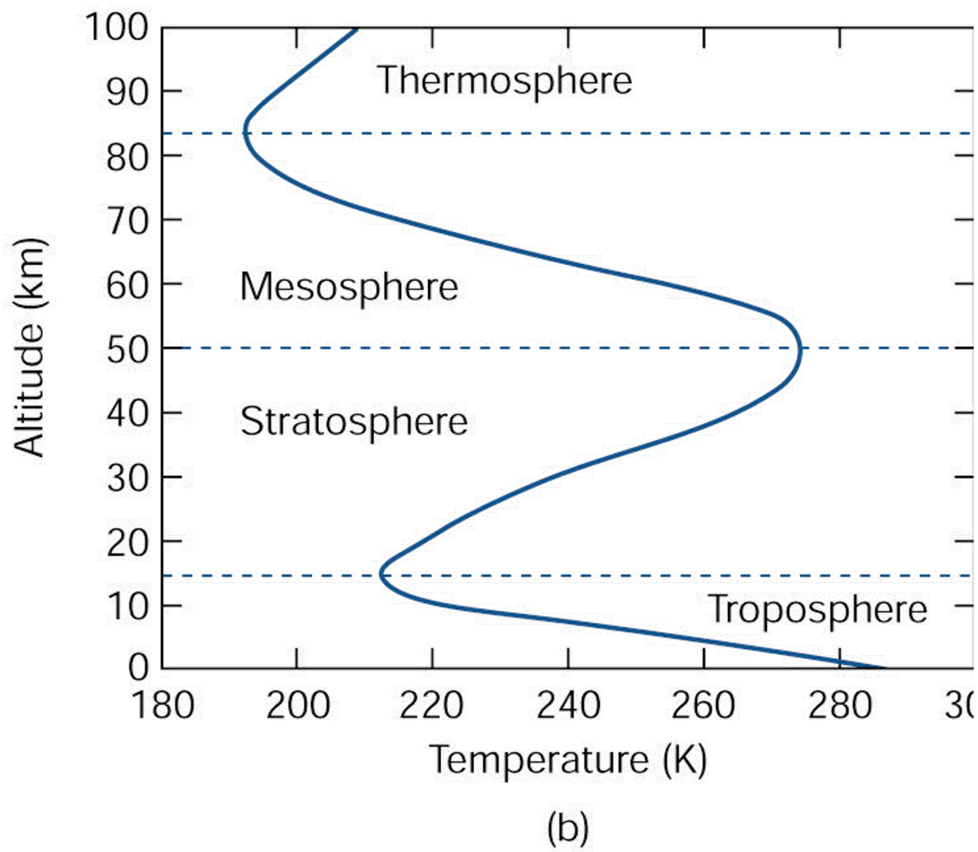
Previous class: continue

(iii) Ozone layer and Ozone depletion

Ozone layer: a chemically distinct region within the stratosphere (part of the earths atmosphere)

Contains most of the Earth's ozone.



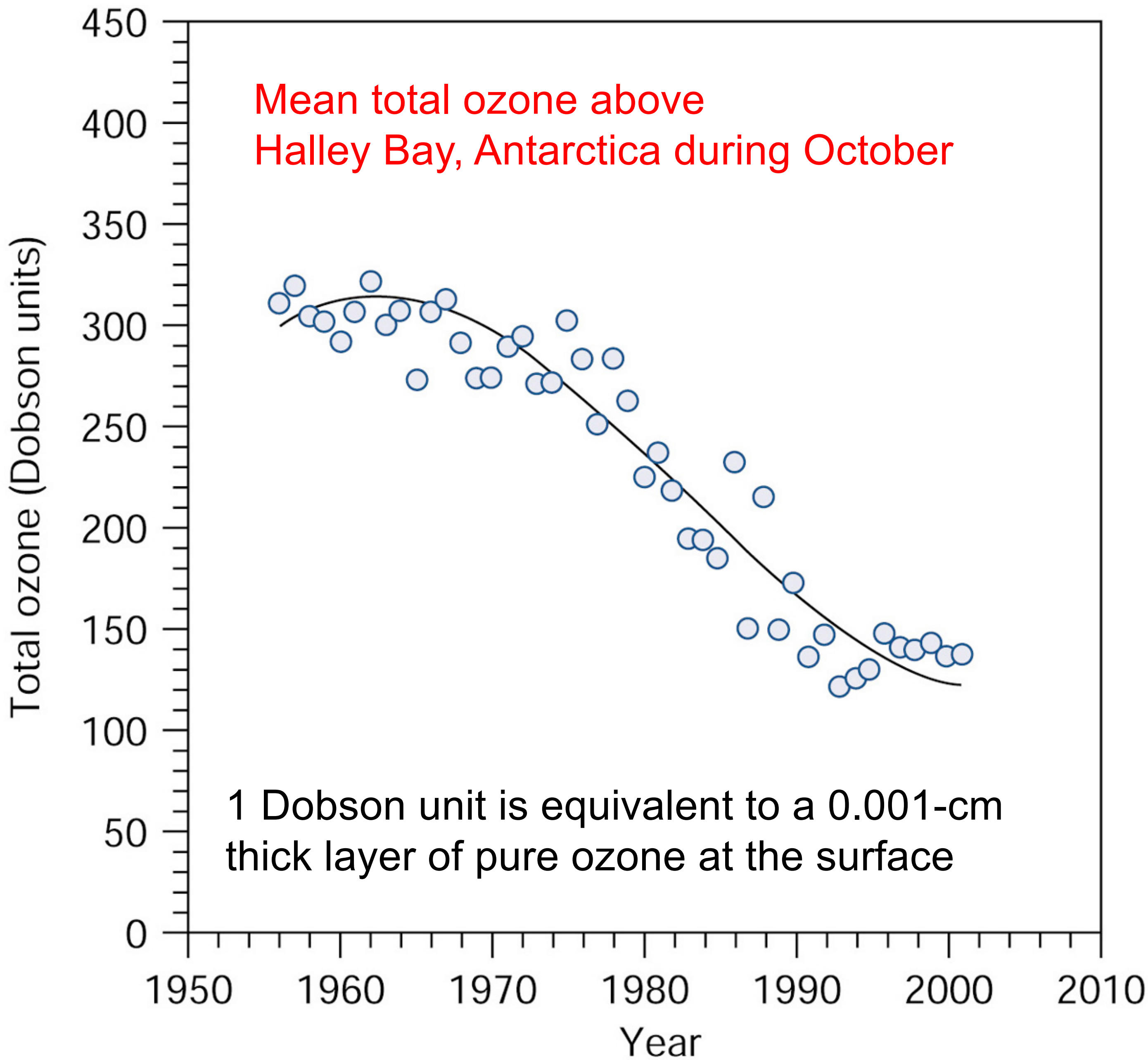


Human impact: Ozone depletion

Ozone layer: Protect Earth's surface from the Sun's Harmful ultraviolet (UV) radiation.

Antarctic ozone hole: In recent decades, a patch of extremely low ozone concentration, is thought to be human origin (freon can destroy ozone)

Observed Ozone Depletion



$$Cl + O_3 \longrightarrow ClO + O_2$$

Chlorine radical

Chlorine monoxide

CFCs (chlorofluorocarbon): transported to stratosphere; break down by UV and become free radicals containing Chlorine. These radicals then break down O3 (rapidly on the surface of polar stratospheric clouds during fall-winter)

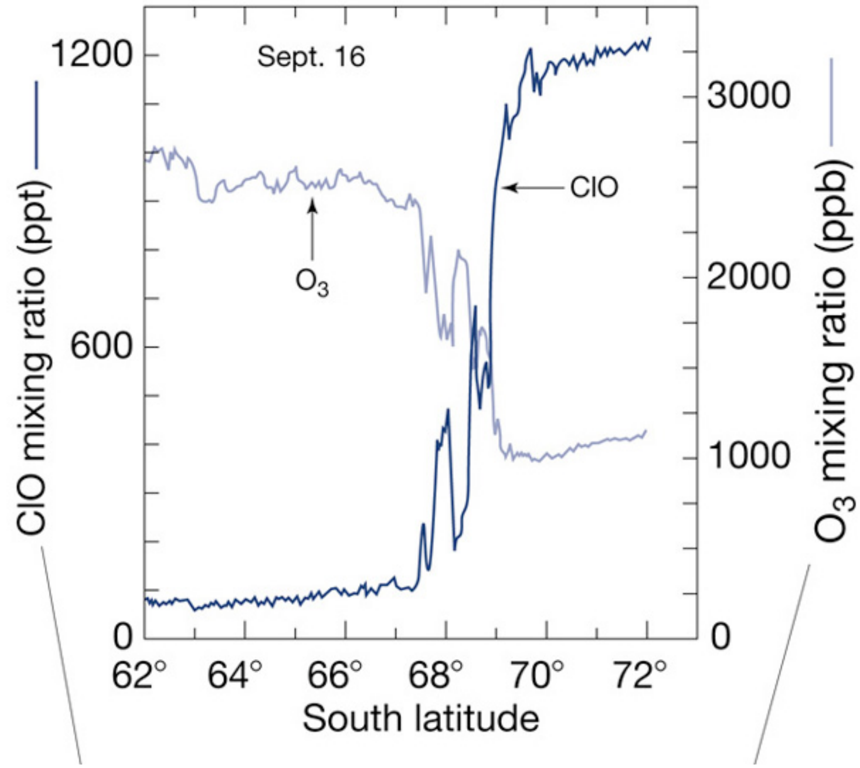
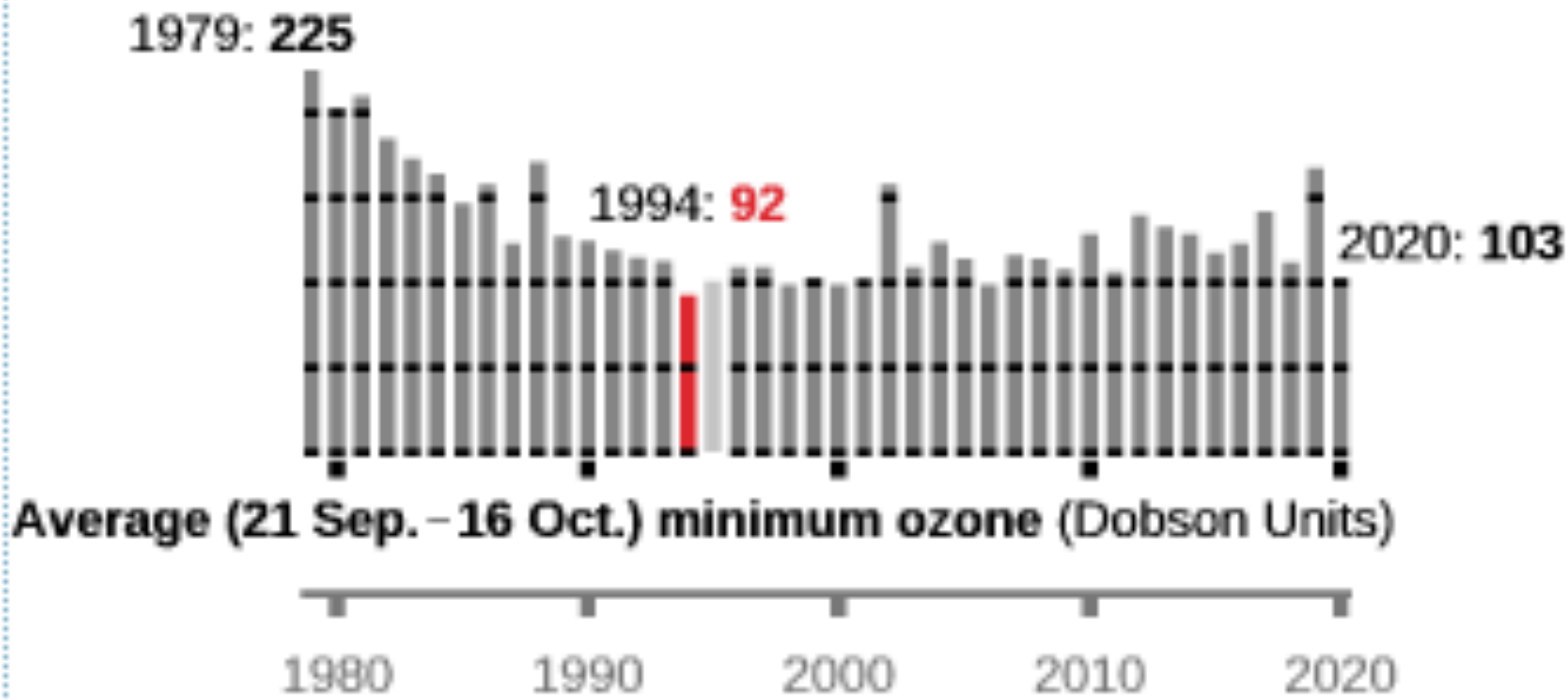


Fig 1-6 Observed Ozone (O3) and chlorine monoxide (ClO). NASA aircraft September 1987.

In 2012, it has been reported that the ozone hole had decreased to the smallest size since 2002. (Comprehensive assessment: healing) **(Ozone hole watch: NASA: https://ozonewatch.gsfc.nasa.gov)**
https://believe.earth/en/recovery-of-the-ozone-layer-brings-hope/



Note: No data were acquired during the 1995 season

(iv) Tropical Deforestation& Land Use/Land Cover Change

Since 10,000 years ago, humans farmed
=> alter land surface. Tropical deforestation
Increases atmospheric CO_2 concentration by 6-17% (Baccini et al. 2012; Nature Climate Change).

We also have northern hemisphere re-forestation in recent years.

Deforestation → lost plant species → lost of animals and microorganisms that live there.

New species may replace them, but normally the number of species decreases: reduce biodiversity.

Land use/land change: affects climate

Polling questions

Today:

Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5), Working Group I (WGI):

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased".

- “Changes in many extreme weather and climate events have been observed since about 1950... It is ***very likely*** that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale... It is ***likely*** that the frequency of heat waves has increased in large parts of Europe, Asia and Australia. There are ***likely*** more land regions where the number of heavy precipitation events has increased than where it has decreased. The frequency or intensity of heavy precipitation events has ***likely*** increased in North America and Europe. In other continents, confidence in changes in heavy precipitation events is at most ***medium***”.

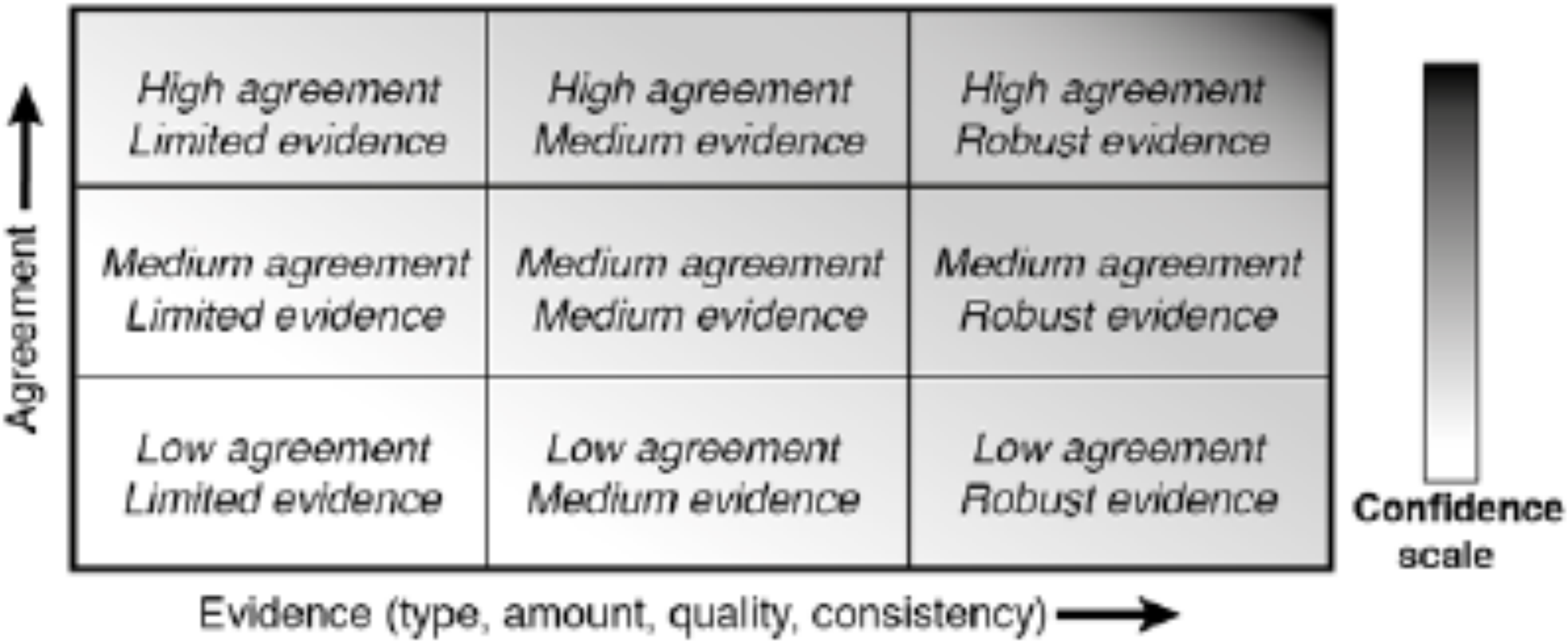
Assessment: Likelihood definition

The following terms have been used to indicate the assessed likelihood:

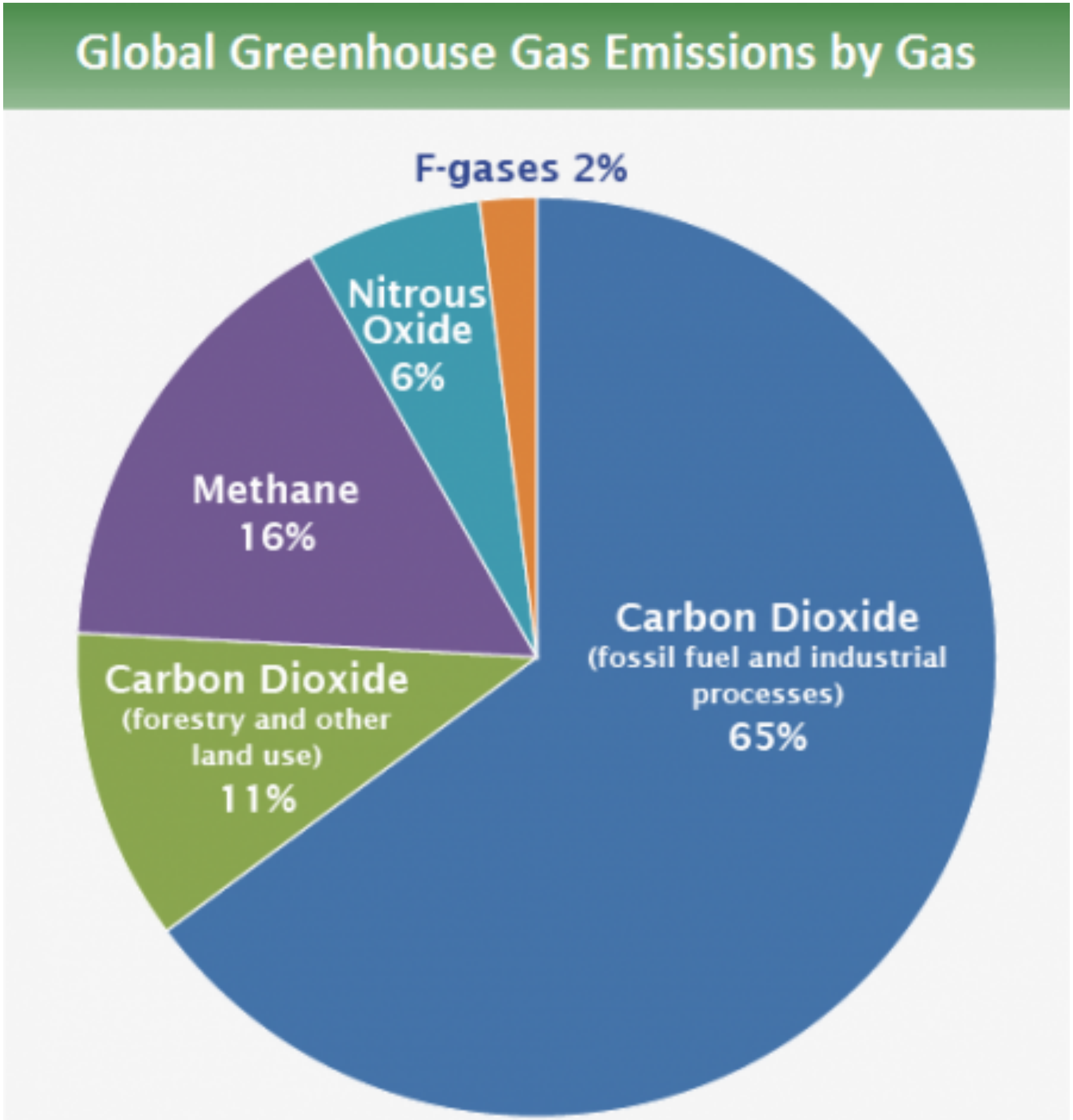
Term*	**Likelihood of the outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms (*extremely likely:* 95–100% probability, *more likely than not:* >50–100% probability, and *extremely unlikely:* 0–5% probability) may also be used when appropriate.

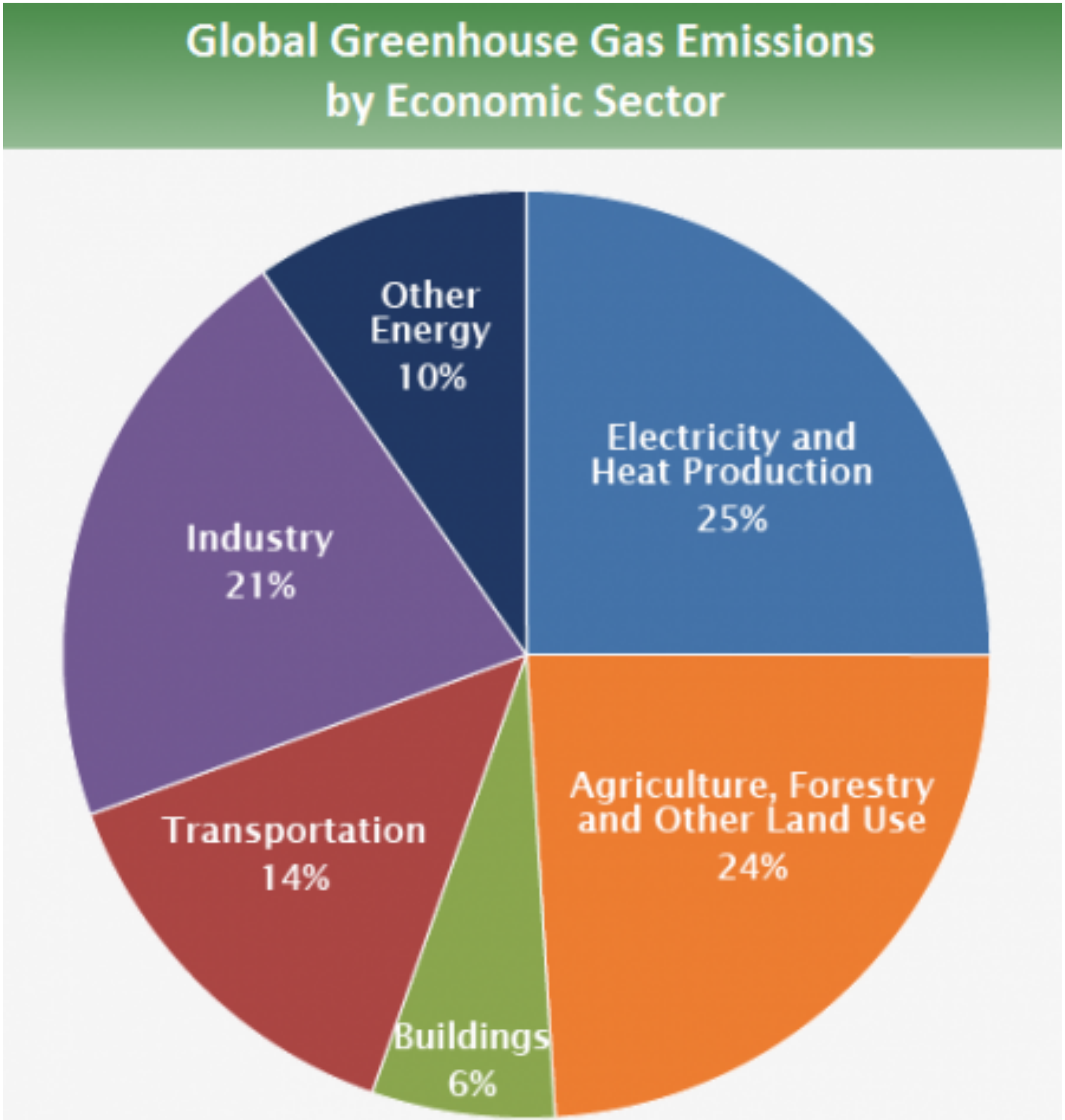
Uncertainty estimates



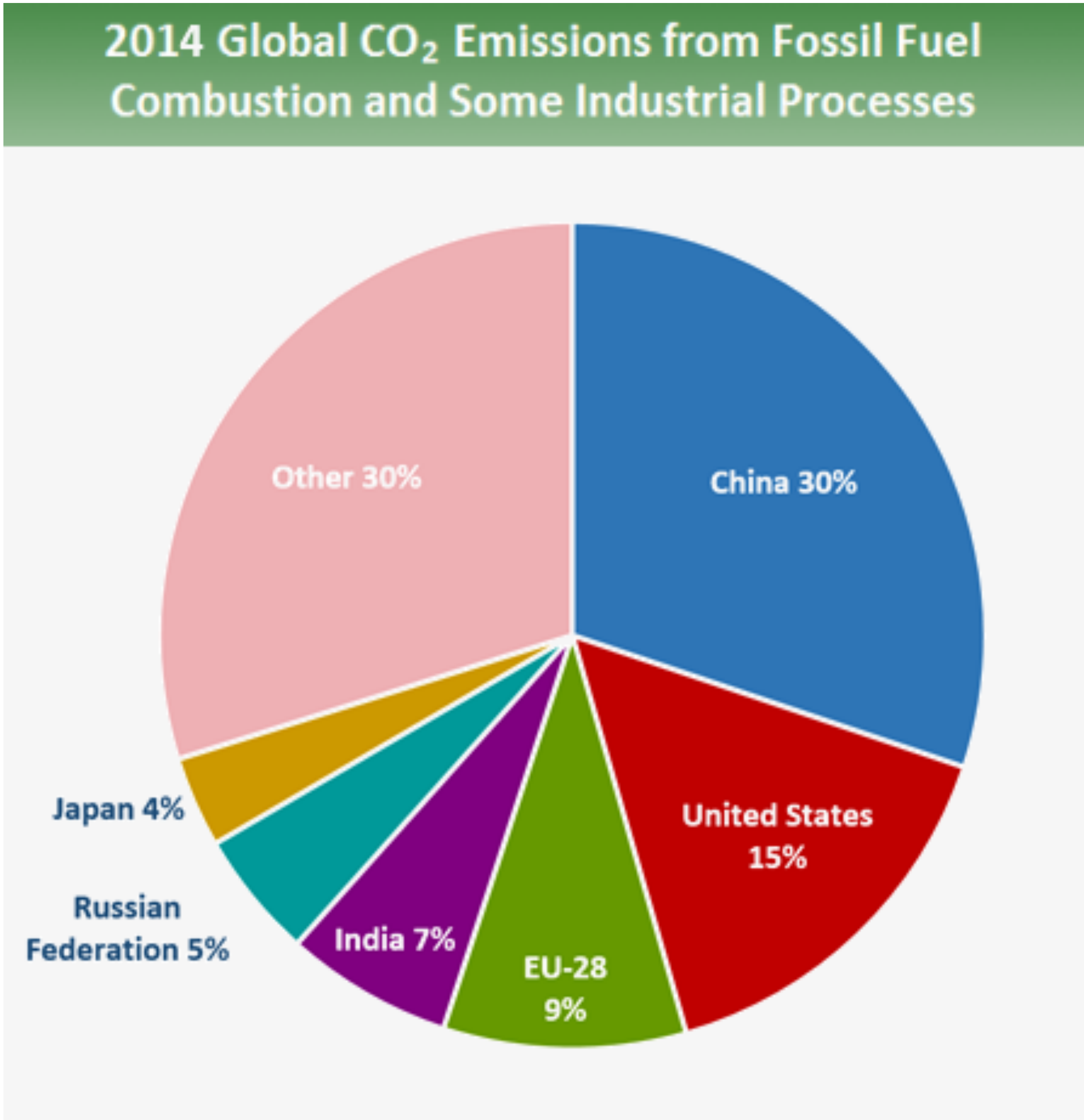
Box TS.1, Figure 1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases toward the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality. {Figure 1.11}



https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

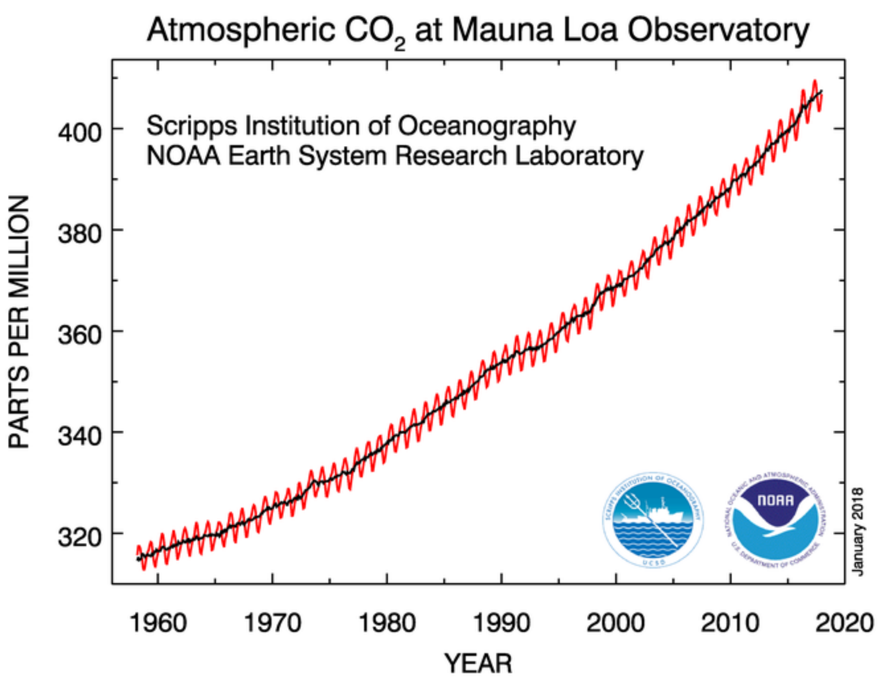


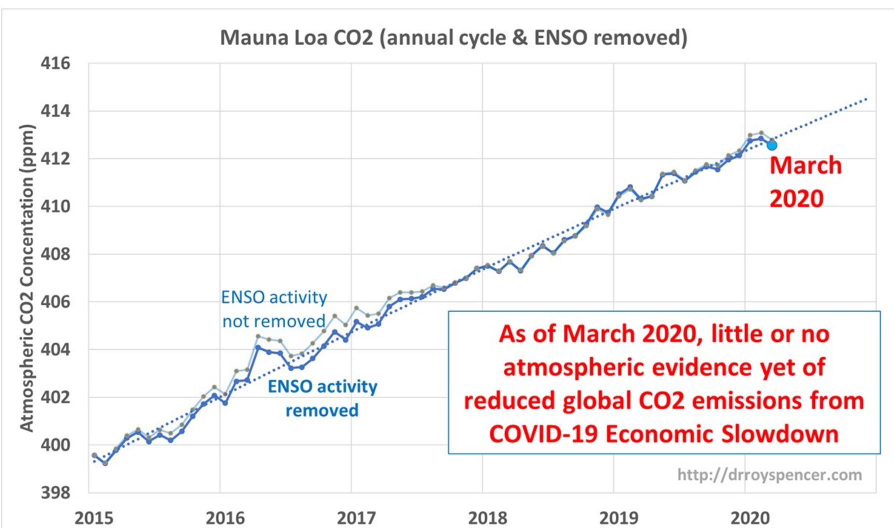
https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

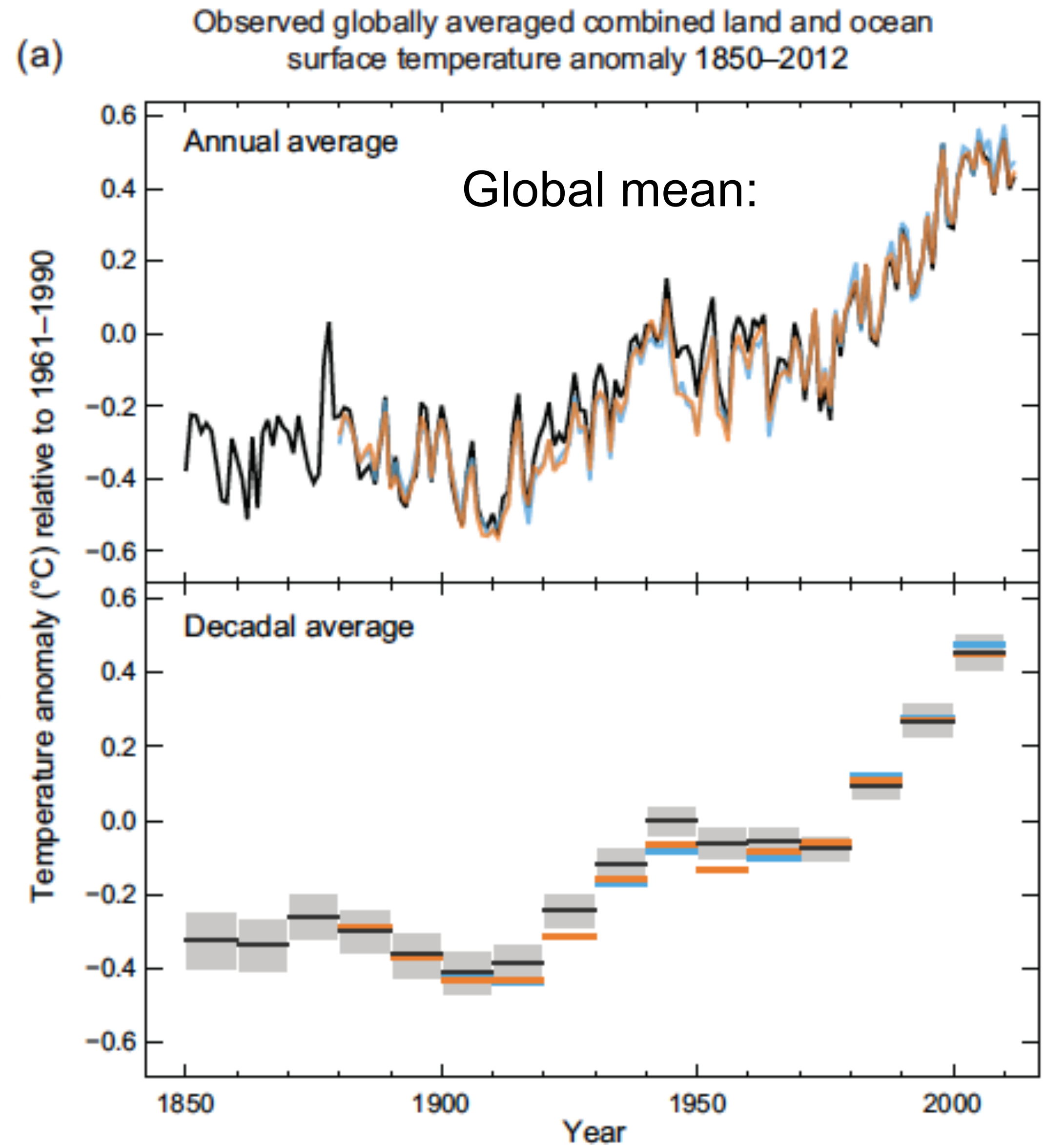


Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, doi 10.3334/CDIAC/00001_V2017.

Observations: The observed GHG & global warming







IPCC AR5, Fig. 1 SPM

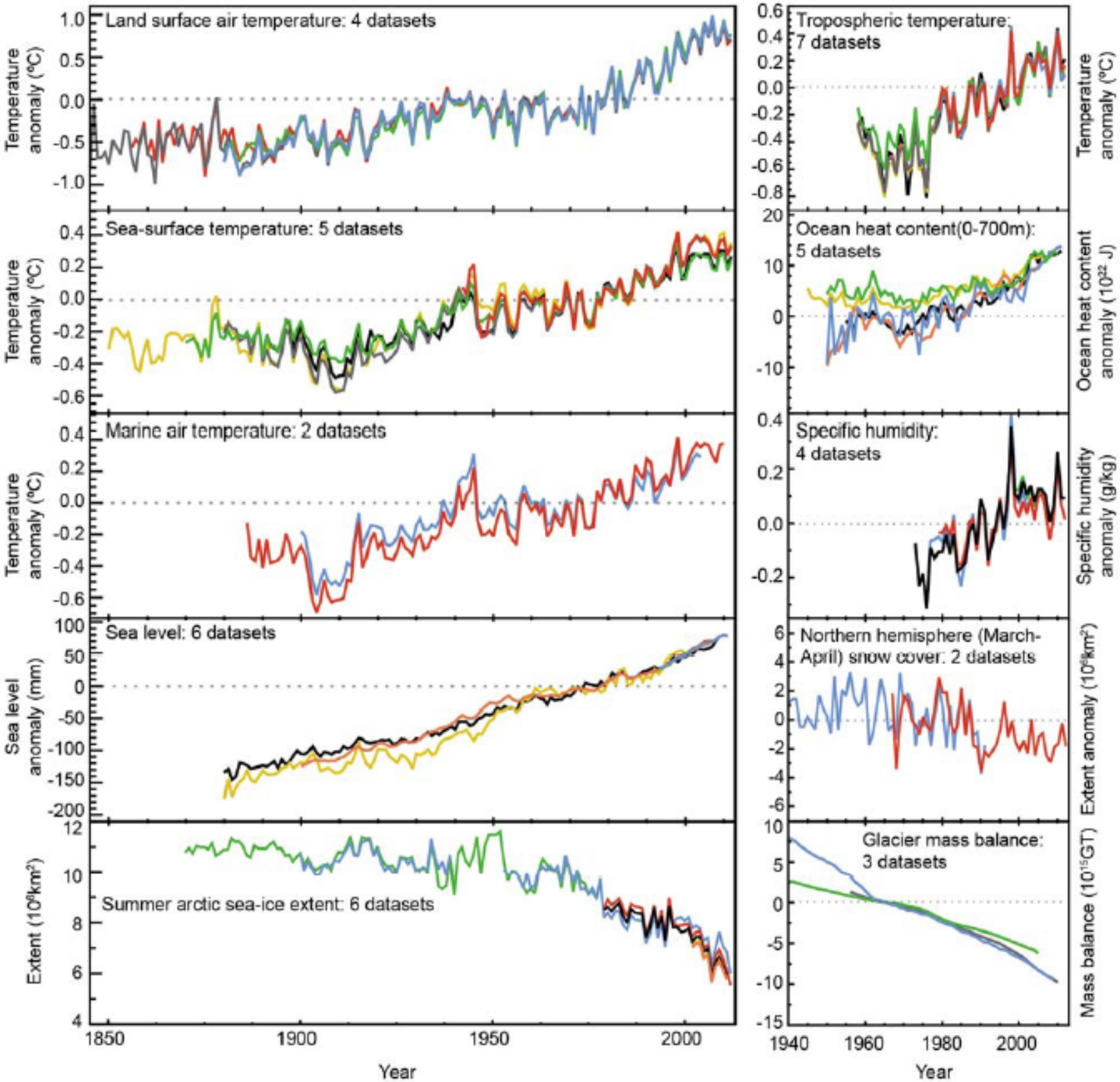


Figure TS.1: Multiple complementary indicators of a changing global climate. Each line represents an independently-derived estimate of change in the climate element. The times series presented are assessed in chapters 2, 3, and 4. In each panel all datasets have been normalized to a common period of record. A full detailing of which source datasets go into which panel is given in Chapter 2, Supplementary Material 2.SM.5 and in the respective chapters (See also FAQ 2.1, Figure 1). {2.4, 2.5, 3.2, 3.7, 4.5.2, 4.5.3}

1.5. Snow cover

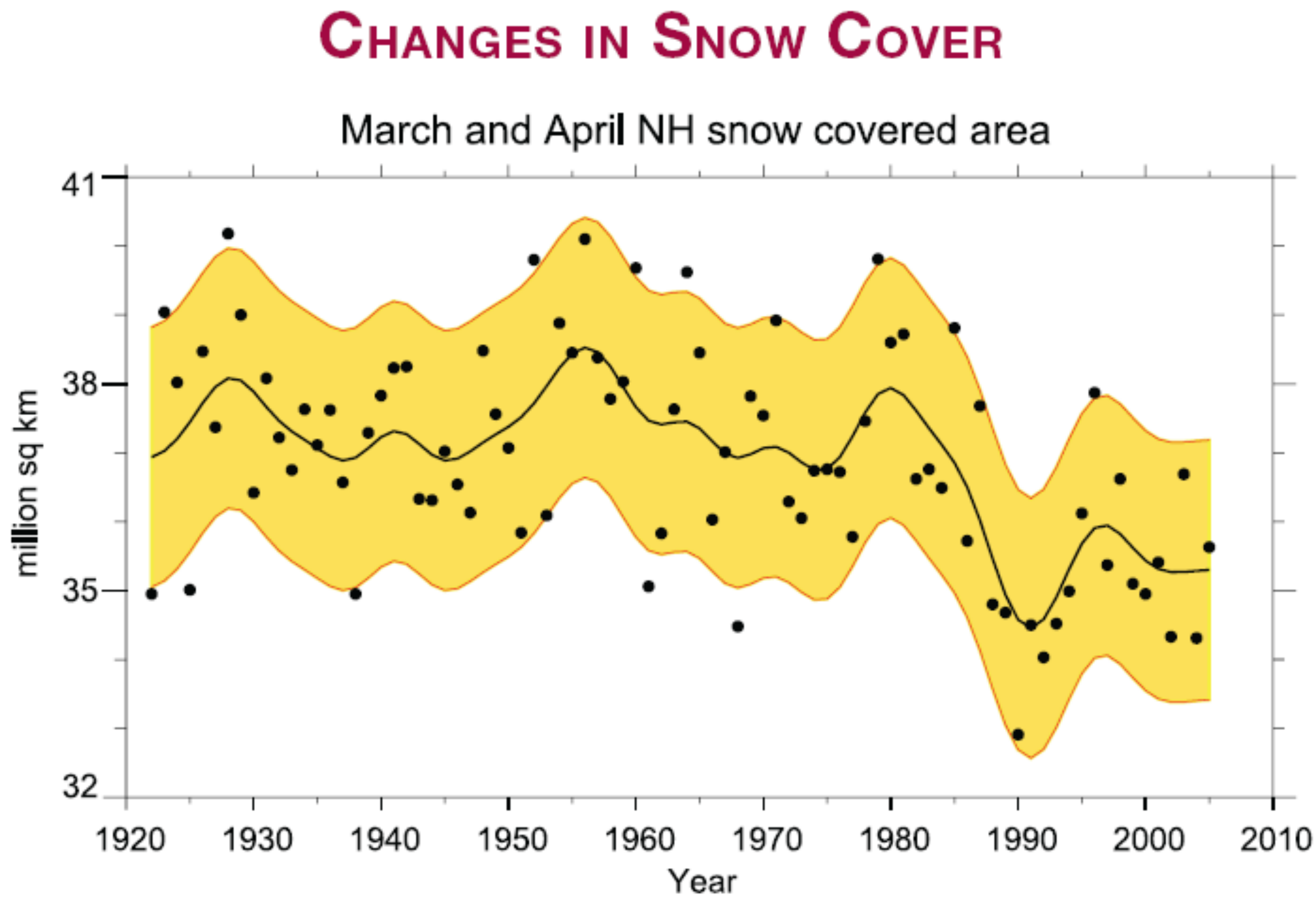
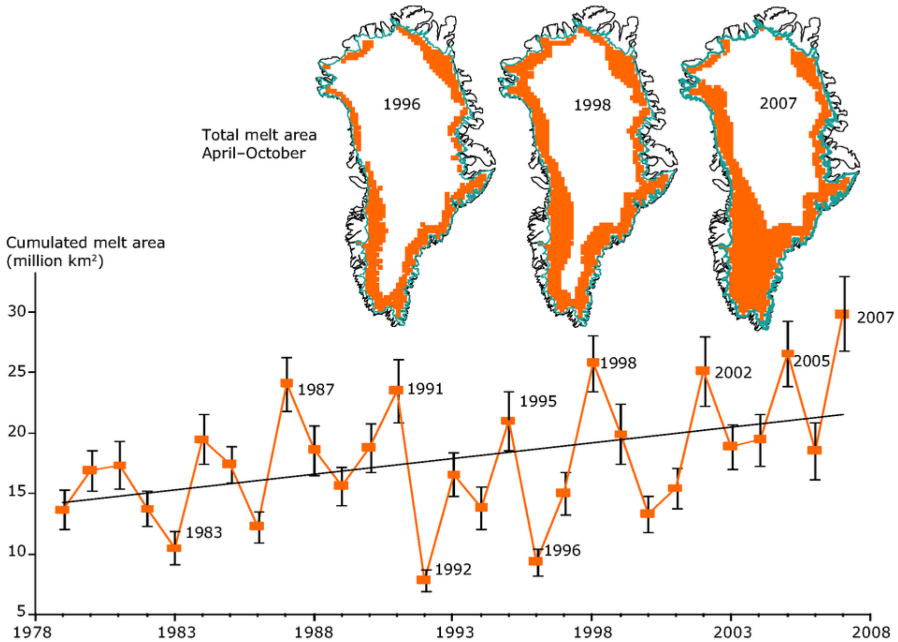
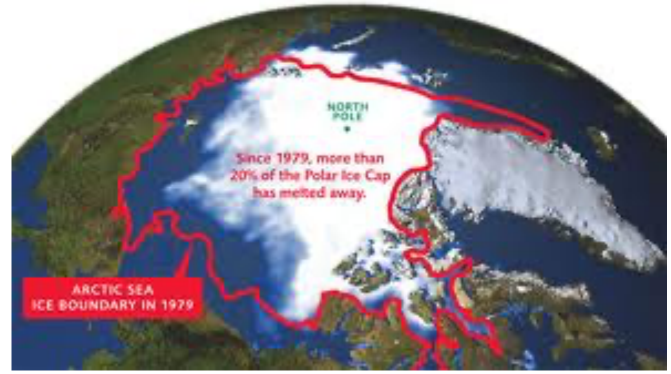


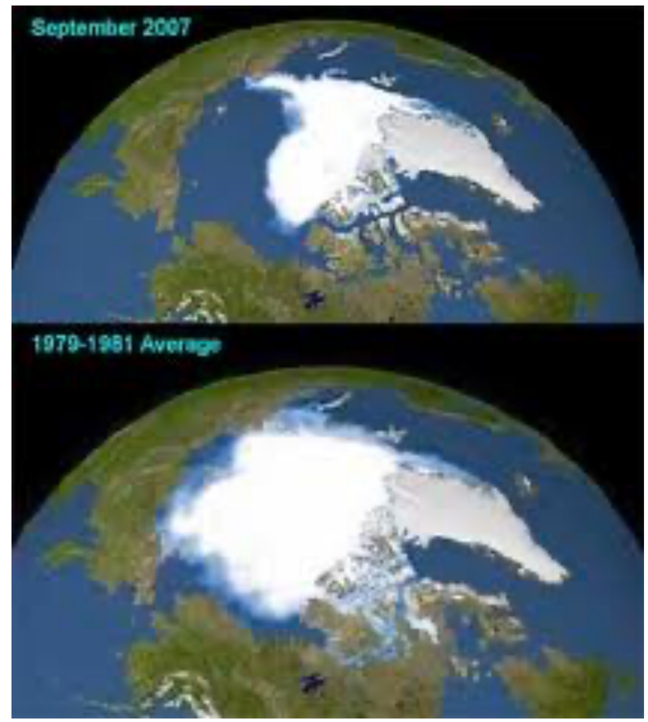
Figure TS.12. (Top) Northern Hemisphere March-April Snowcovered area from a station-derived snow cover index (prior to 1972) and from satellite data (during and after 1972). The smooth curve shows decadal variations (see Appendix 3.A) With the 5 to 95% data range shaded in yellow.

1.6. Ice sheet



http://www.eea.europa.eu/data-and-maps/data-providers-and-partners/international-glaciological-society





http://ecoble.com/2008/01/11/how-can-you-question-climate-change-now/

It is ***likely that the Antarctic ice sheet loss has increased*** from 1992-2001 to 2002-2011;

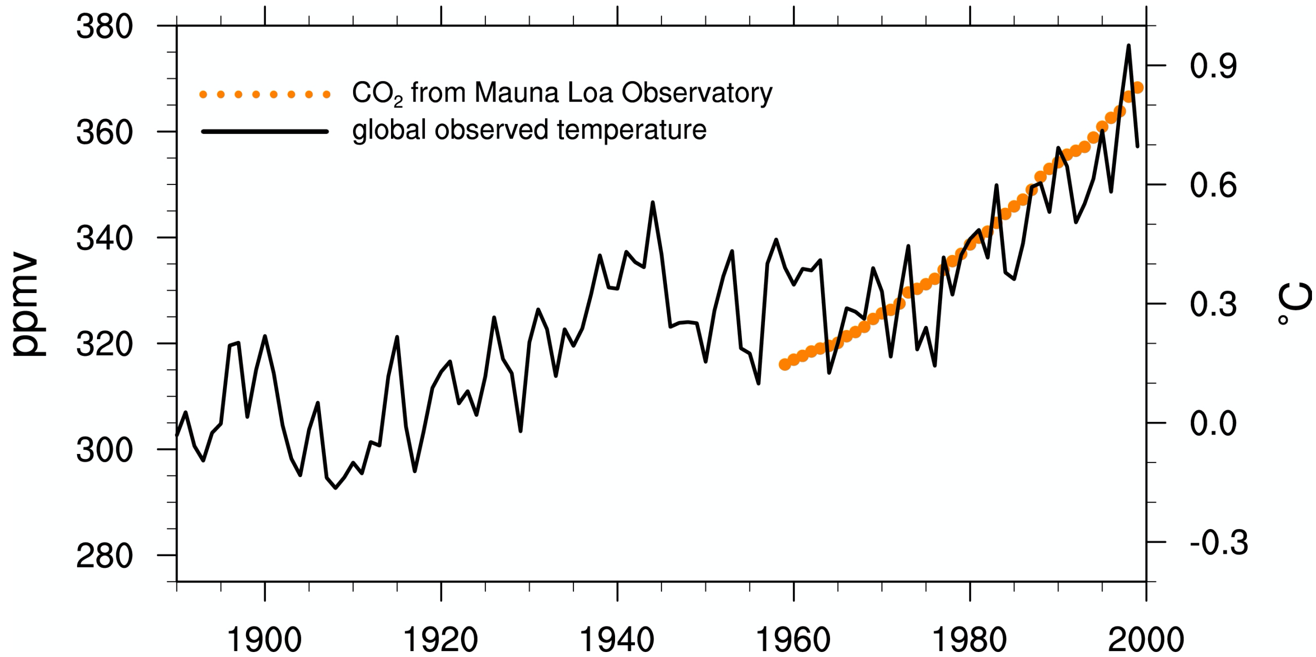
It is ***Very likely that Antarctic Sea ice extent increased*** at a rate of 1.2-1.8%/decade from 1979-2012

Upsala glacier in the Andes, Argentina

1932

1988

Figure 5. Boulder Glacier: 1932 (left), 1988 (right). These two views of Boulder Glacier demonstrate the dramatic reduction in ice in Glacier National Park and its ecological consequences. Vegetation has moved in where the ice cave used to be. Photo-



Critical thinking: why didn't the globally averaged surface temperature warm monotonically even though human-produced greenhouse gases were increasing the whole time?

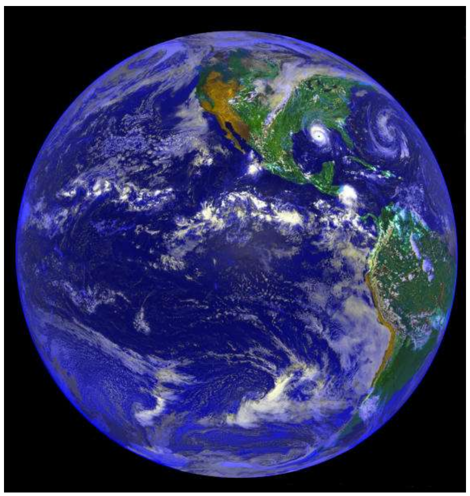
Is increased CO_2 the cause for the upward trend? How can we know?

We need a tool:

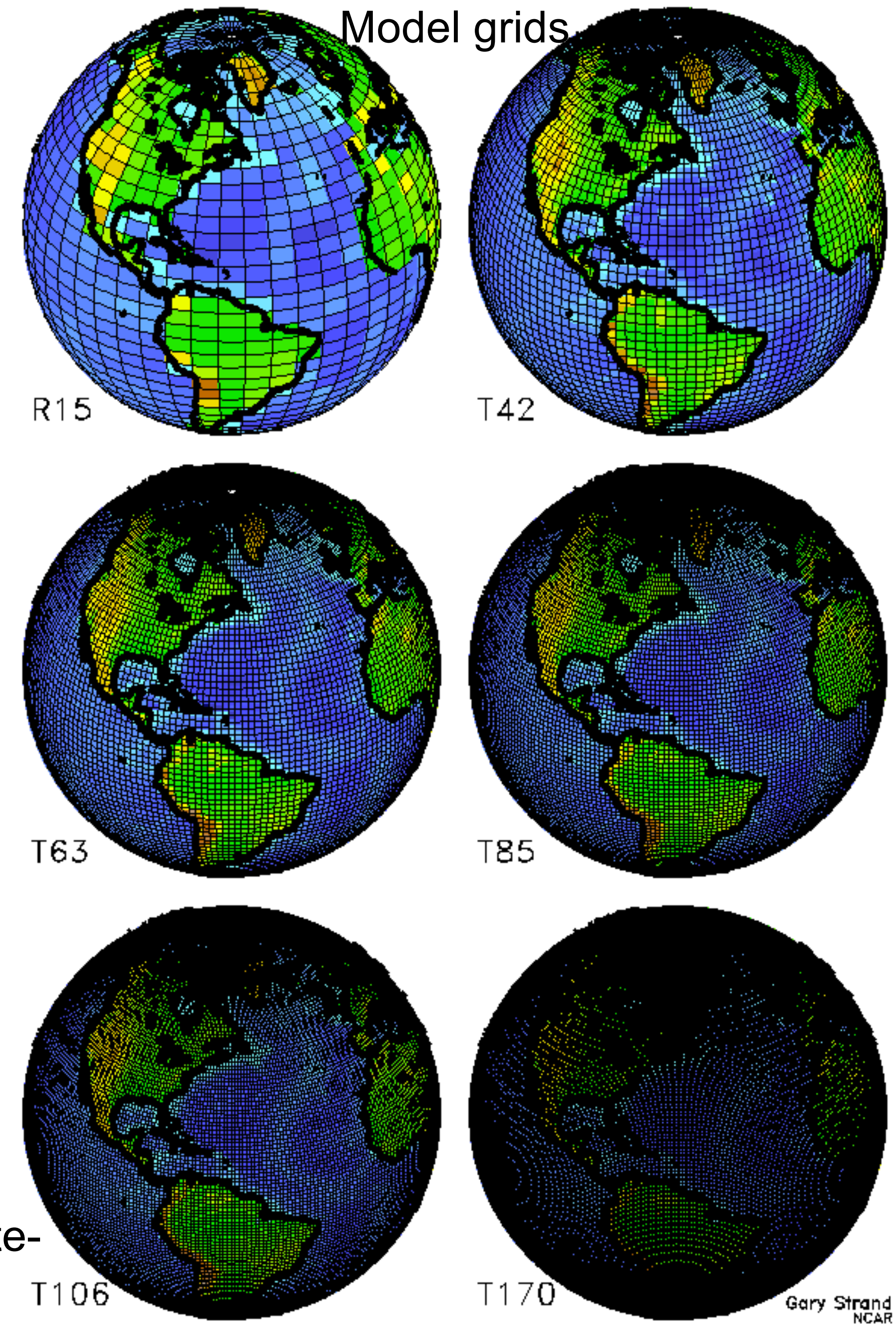
climate models can be used to address this mystery …

Attribution: climate model simulation

Can we simulate the earth's climate with equations?



Real Earth



https://scied.ucar.edu/longcontent/climate-modeling

Observed/simulated global mean surface temperature

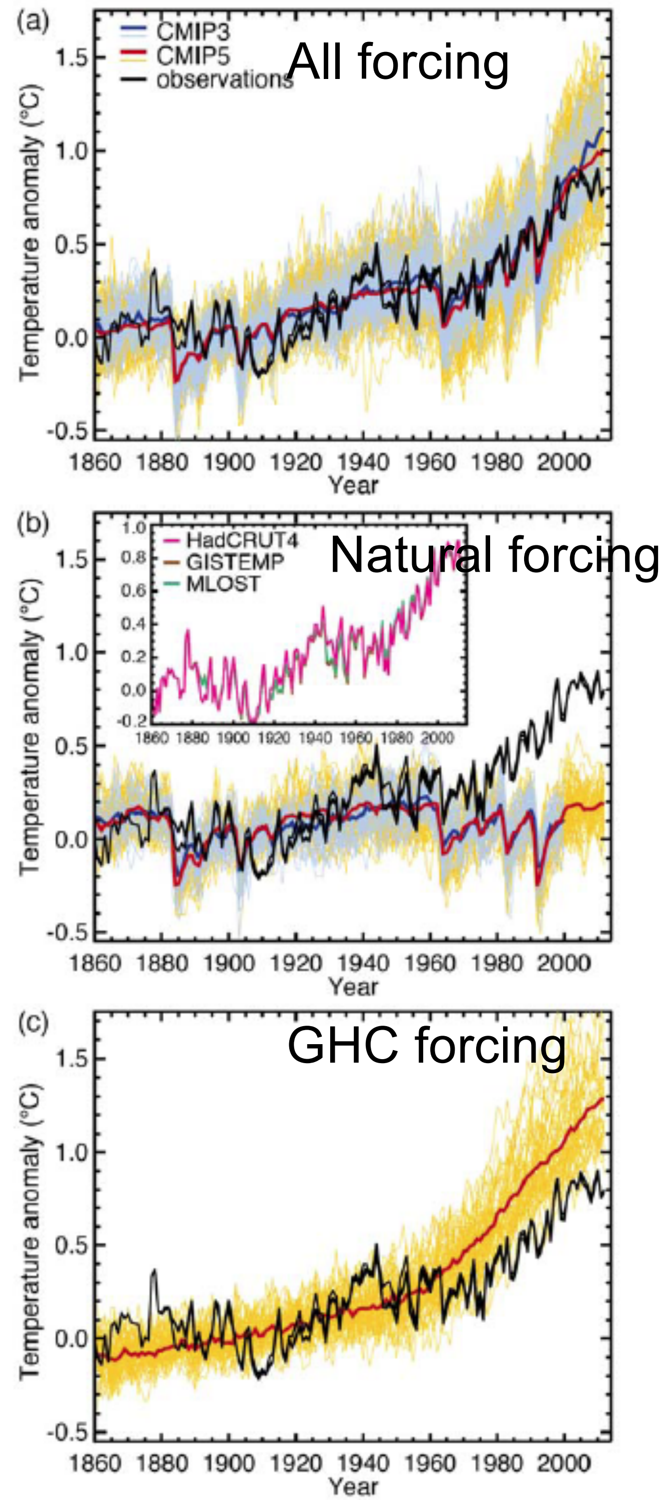
Concept: Climate model experiment ensemble:
A set of model runs with different initiation conditions. There are spreads among ensemble members, due to natural internal variability.

Ensemble mean for many members: measures the variability forced by "external forcing".

Observations: "like a single member", one realization

AR5: "…*It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century. (10.3-10.6, 10.9)*

Figure TS.9: Three observational estimates of global mean surface temperature (black lines) from HadCRUT4, GISTEMP, and MLOST, compared to model simulations (CMIP3 models – thin blue lines and CMIP5 models – thin yellow lines) with anthropogenic and natural forcings (a), natural forcings only (b) and greenhouse gas forcing only (c). Thick red and blue lines are averages across all available CMIP5 and CMIP3 simulations respectively. All simulated and observed data were masked using the HadCRUT4 coverage (since this dataset has the most restricted spatial coverage), and global average anomalies are shown with respect to 1880–1919, where all data are first calculated as anomalies relative to 1961–1990 in each grid box. Inset to (b) shows the three observational datasets distinguished by different colours. {Figure 10.1}



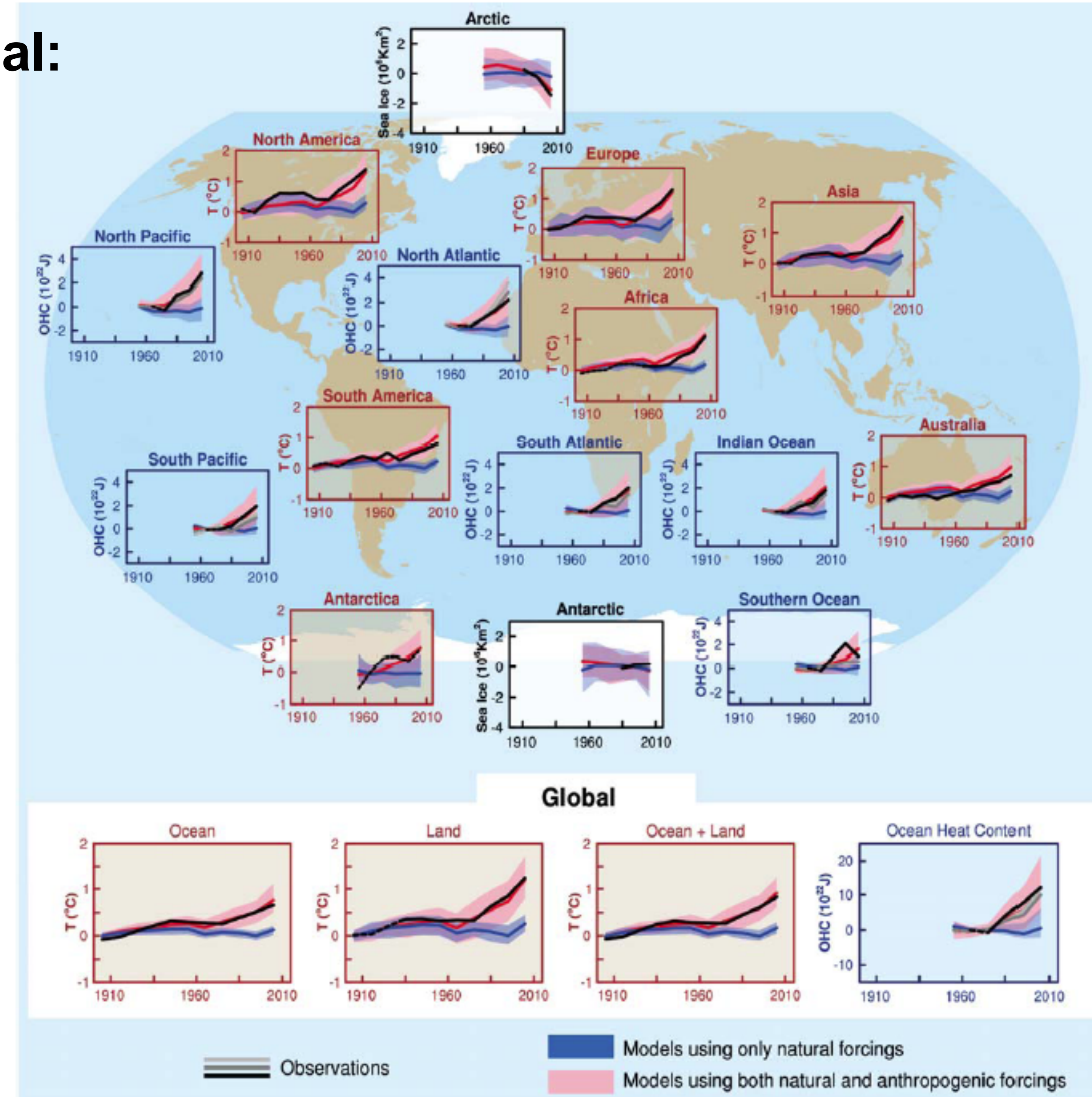
Regional and global:

Surface temperature;
Ocean heat content;
Sea ice extent

Black: Observed

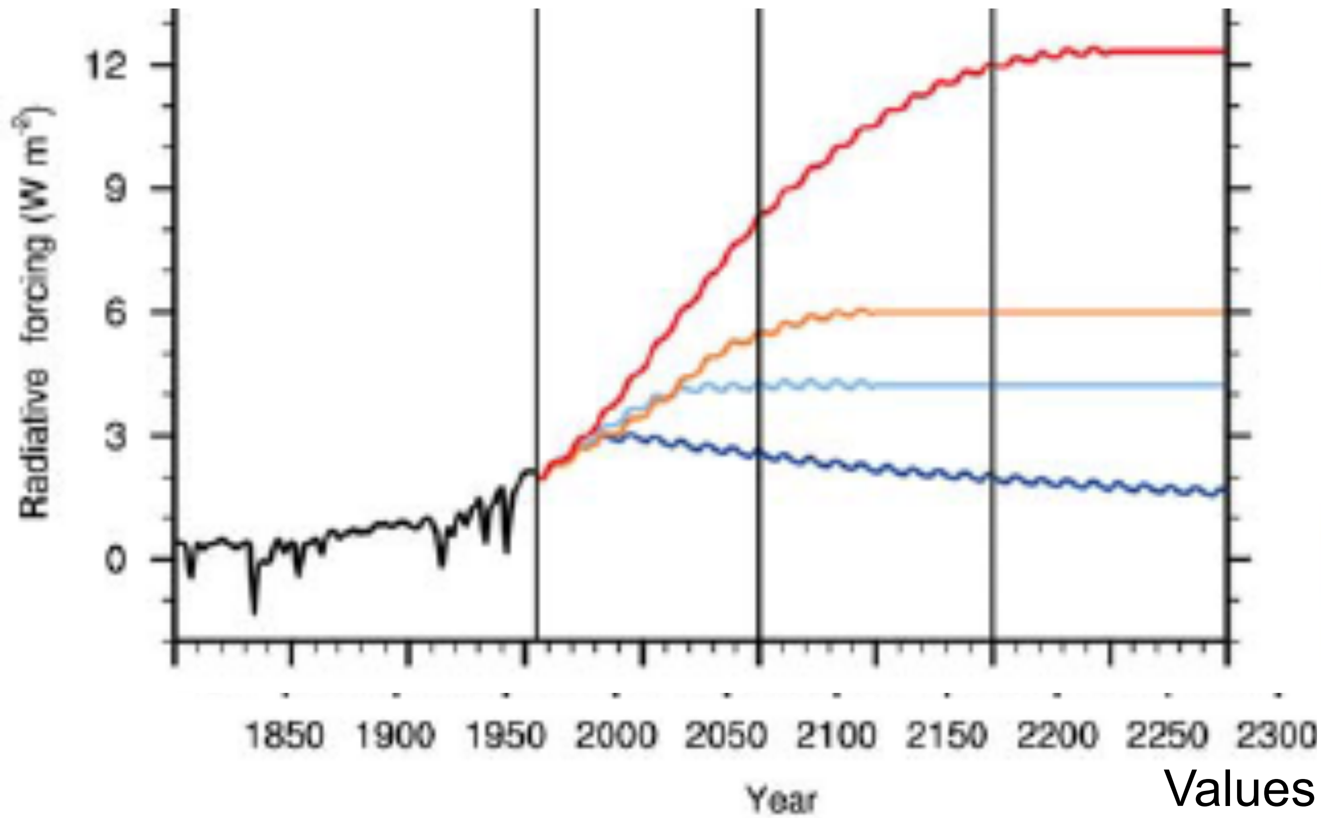
Read: Simulated
All forcing

Blue: Simulated
Natural forcing only



Future projection: Green House Gas (GHG)

Representative concentration pathway (RCP) scenarios



RCP8.5 (936/1313)

RCP6.0 (670/800)

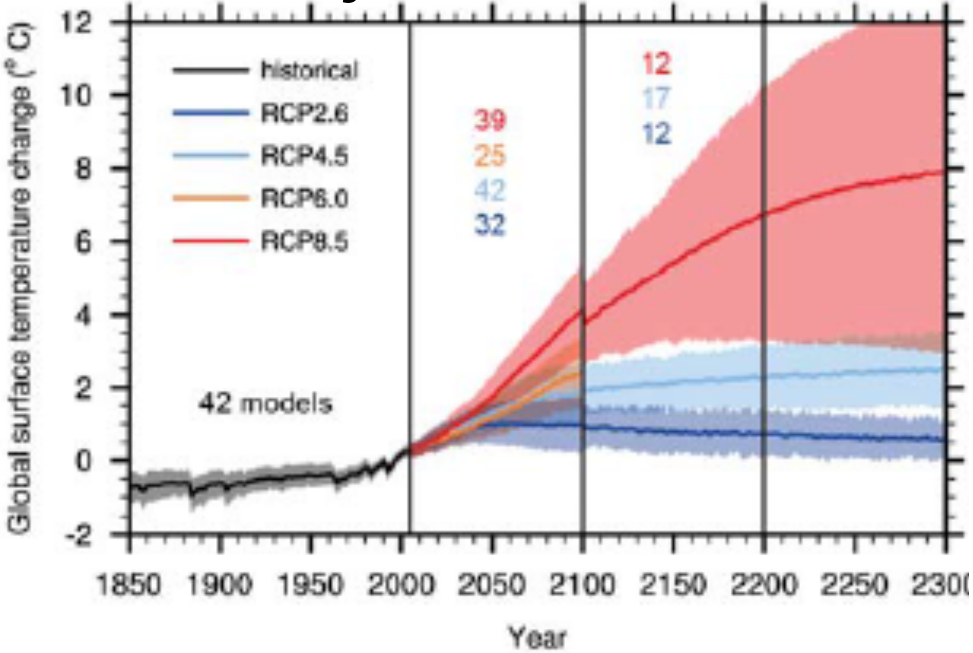
RCP4.5 (538/630)

RCP2.6 (421/475)

Values in the Parentheses are CO2/(CH4,N2O+ Combined CO2 equivalent in ppmv)

RCP6.0: Radiative forcing=6.0w/m2 in yr 2100 relative to 1850 induced by Anthropogenic GHG emission

Future Projection:



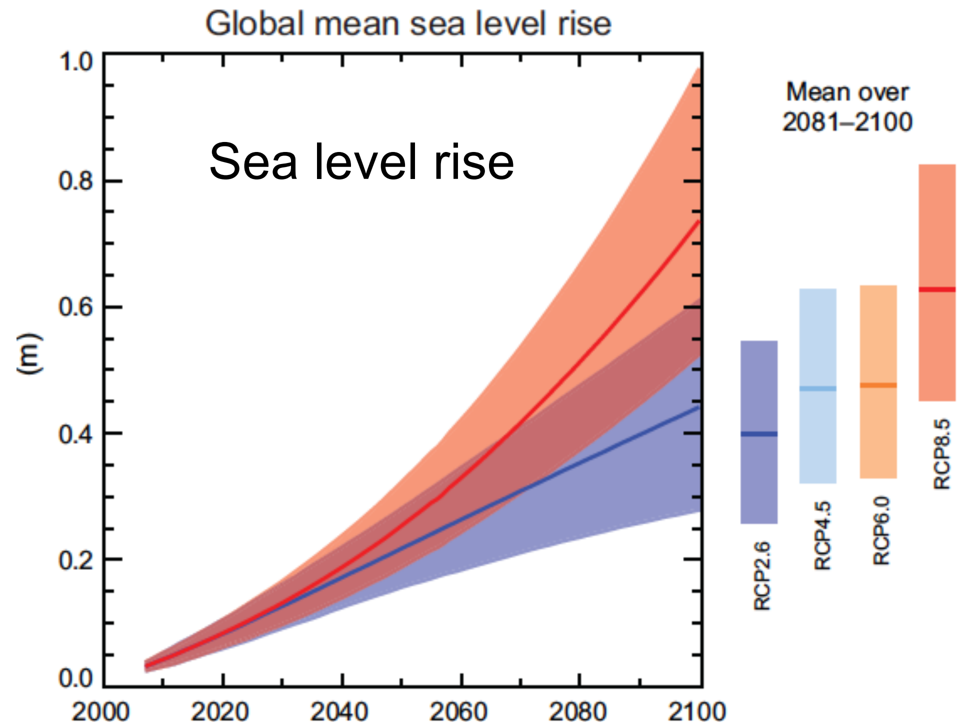


Table SPM.2 | Projected change in global mean surface air temperature and global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005. {12.4; Table 12.2, Table 13.5}

		2046–2065		2081–2100	
	Scenario	**Mean**	***Likely* range[c]**	**Mean**	***Likely* range[c]**
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	**Mean**	***Likely* range[d]**	**Mean**	***Likely* range[d]**
Global Mean Sea Level Rise (m)[b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Impacts & policies

GHG emission ⟶ Global warming ⟶
Impacts:

Impacts global climate (e.g., intensified hydrological cycle: climatologically "rich gets richer") & weather (e.g., heat waves, Atlantic hurricanes), sea level, ecosystems, etc.;

Policies? (Role of science in formulation of policy)
(a)Adaptation
(b)Mitigation

Policies? (a) Adaptation

- Adaptation measures are necessary, irrespective of the scale of mitigation measures

Even if CO_2 stops increasing,
global temperature will still increase by ~0.6° C in the next century;
Adaption is necessary, even though adaptation alone may not be sufficient.

Adapting to sea level rise: Developing countries: Bangladesh, Vietnam, the Maldives


Shafiqul Islam/WPN

https://www.youtube.com/watch?v=xWG_uzLmuug

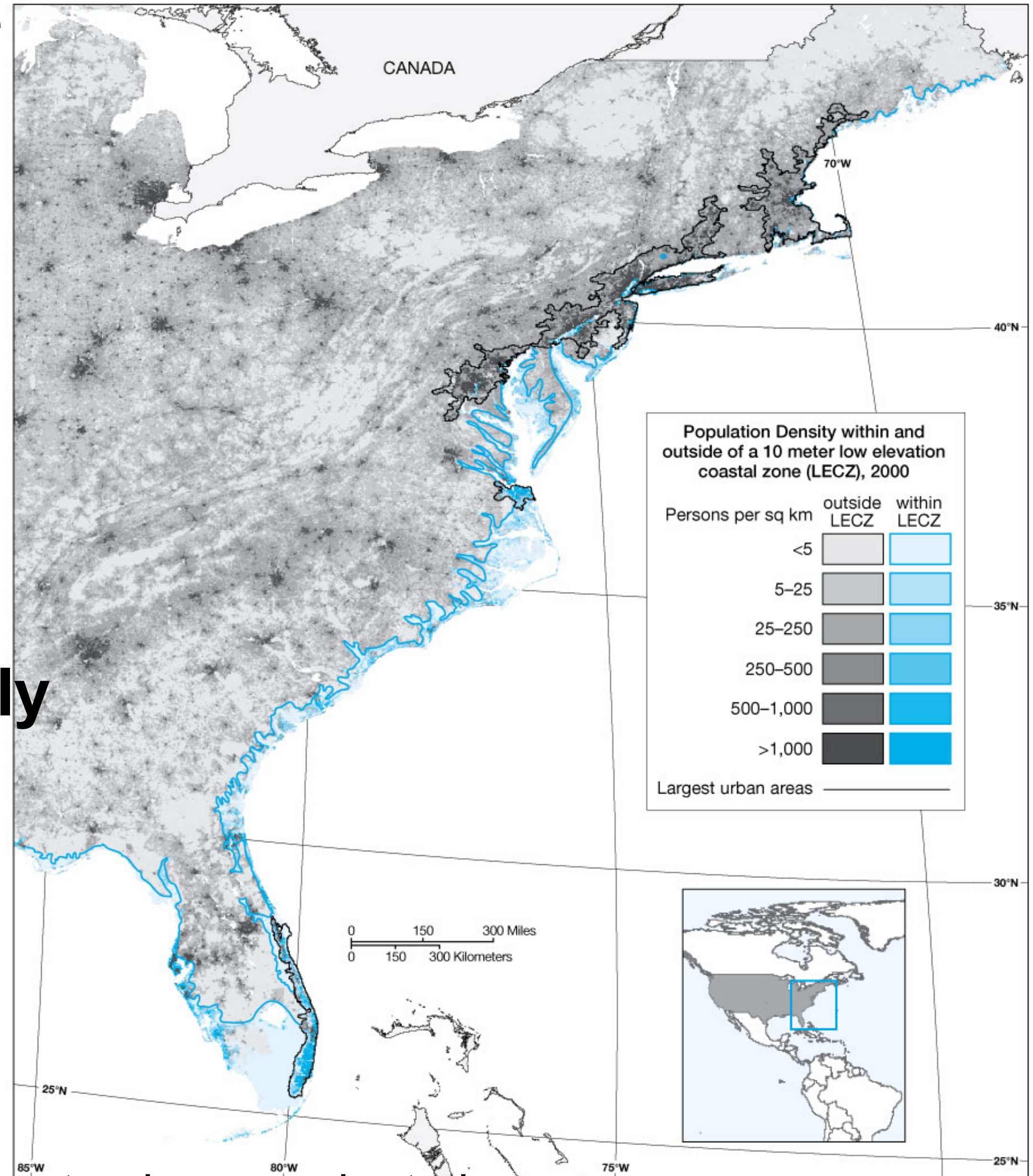
Adapting to Sea level rise:

The USA- 20 million people live in LECZ (low elevation coastal zone);

Dikes, dams;

Building flood-proof structures, floating agricultural systems;

Move inland.



Adapting to water supply:

Find ways to increase supply & reduce demand:

prospecting ground water, collect rainwater, larger reservoir, process sea water, reuse, minimize irrigation, urban – metering, pricing)

https://www.epa.gov/arc-x/strategies-climate-change-adaptation

The Netherland's Billion Dollar Sea Wall

Dikes

Armoring

(b) Mitigation

Mitigation of global warming – will cost: IPCC AR4

Policies:

Top-down studies

Assess the economy-wide potential of mitigation options.
Use globally consistent frameworks **and aggregated information about mitigation options and capture macro-economic and market feedbacks**

Bottom-up studies

Assess mitigation options, emphasizing specific Technologies and regulations. They are typically *sectoral* studies taking the macro-economy as unchanged.

Top-down & bottom-up policies – getting more similar since one is mixed with the other

United Nations
Framework Convention on
Climate Change

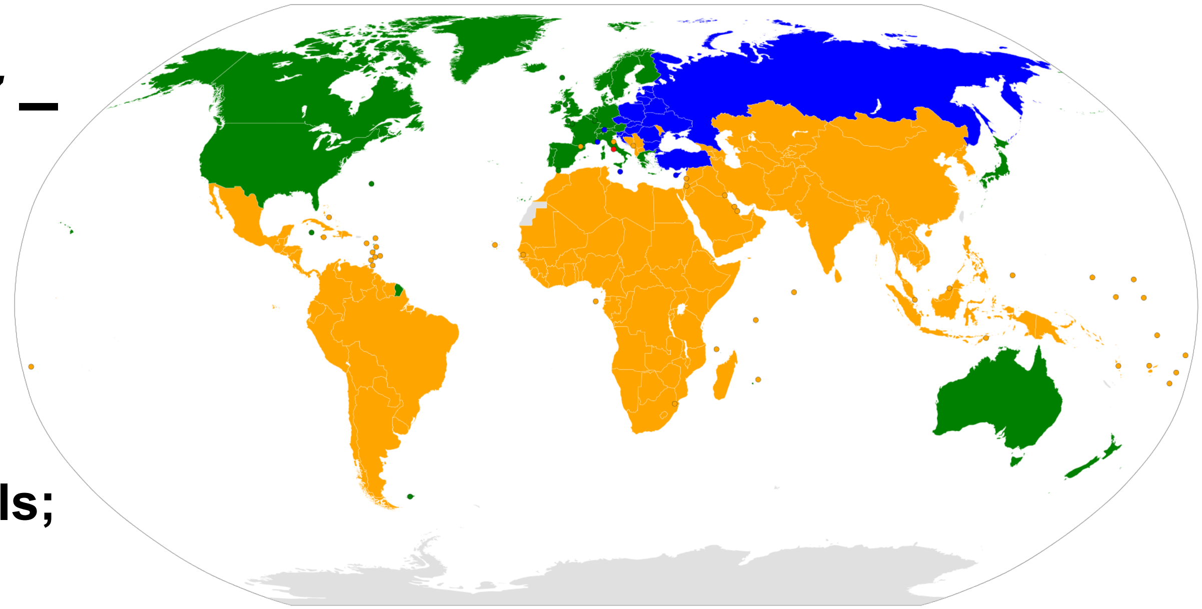
Top-down:
e.g., carbon taxes, stabilization policies

The Kyoto Protocol: 1997 – hard measure:

Two commitment periods:
Treaty: economically developed countries: USA, Europe, Japan, etc., cut CO_2 emissions to 5% below 1990 Levels; 1st (2005-2012), 2nd (2012-2020).
The US has not ratified;

(China& India: high emissions but are not in the protocol)

All Annex I but the US participated in the 1st period; 2nd period – 37 Annex I countries & EU agreed. Japan, New Zealand, & Russian, US & Canada – have not had 2nd round targets.



197 Parties to the UNFCCC:
Green: Annex I and II parties
Blue: Annex I parties
Orange: Non-annex parties
Red: Observer states

UNFCCC parties agreed to further commitments

Bali Action Plan (2007), the Copenhagen Accord (2009), the Cancun agreements (2010), & the Durban Platform for Enhanced Action (2012).

Cancun agreements: "Global warming should be limited to below 2.0C (3.6F) relative to pre-industrial level.
Durban Platform – parties agreed to "develop a protocol, …",

Paris agreement:
Signed in Dec 2015; Entered into force: Nov 2016;

June 1st, 2017, President Trump announced that US will withdraw from the Paris agreement (can't do so yet until 2020)

UNFCCC parties agreed to further commitments:

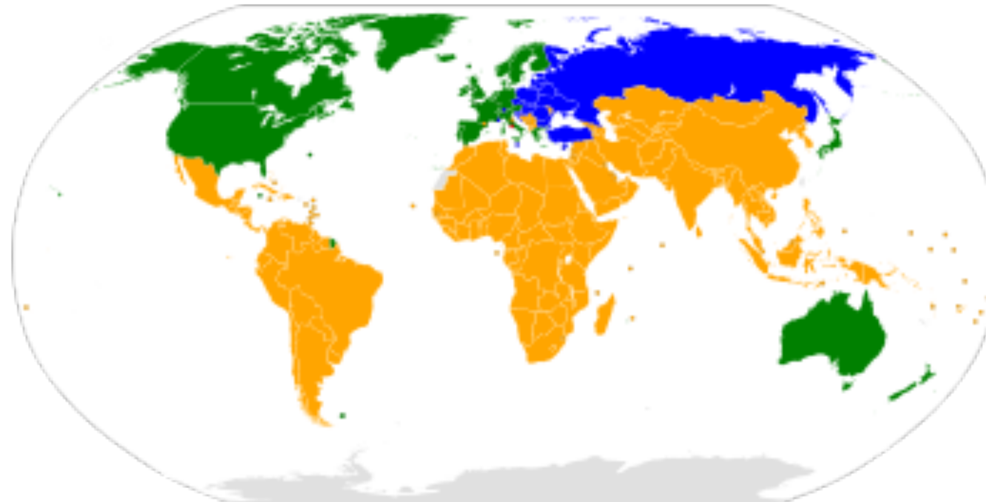
Paris agreement and ractification status:
https://unfccc.int/process/the-paris-agreement/status-of-ratification

The Paris Agreement central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives. The Agreement also provides for enhanced transparency of action and support through a more robust transparency framework.

Top-down:

United Nations
Framework Convention on
Climate Change

Paris agreement:
Of 197 UNFCCC parties representatives, 184 have ratified
unfccc.int/paris_agreement/items/9444.php



https://unfccc.int/katowice

Conference of the Parties (COP) 24:
Dec 2-14 2018, Katowice, Poland;

197 Parties to the UNFCCC Dec 2015:
Green: Annex I and II parties
Blue: Annex I parties
Orange: Non-annex parties
Red: Observer states

Conference of the Parties (COP) 24: Dec **2-14 2018**, Katowice, Poland;
Paris agreement:

Bottom up: Key mitigation technologies and practices by sector (AR4)

- **Energy supply:** (efficiency, fuel switching coal to gas, renewable energy – solar, hydropower, wind, bioenergy, geothermal, carbon capture and storage, etc.)
- **Transport:** (fuel efficient & hybrid vehicles, biofuels, shift of transport system, etc.)
- **Buildings**: Leadership in Energy&Environmental Design(LEED), etc.
- **Industry**: (more efficient end-use electrical equip.; recycling, Technologies, Carbon dioxide capture and storage (CCS), etc.)
- **Agriculture:** (improved crop/land management, livestock management to reduce CH4, etc.)
- **Forestry/forests:** (Afforestation; reforestation; forest management)
- **Waste management:** (landfill methane recovery; organic waste compositing, recycling, etc.)

NOTE:

These policies didn't consider lifestyle change;

After AR4 2007: Many technologies have already been implemented regionally (e.g., Solar PV incentives).

Policies: IPCC AR5

Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases.

Mitigation, together with adaptation to climate change, contributes to the objective expressed by the UNFCCC:

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Climate policies can be informed by the findings of science, and systematic methods from other disciplines.

Policies: Economic evaluation is commonly used to inform climate policy design;

consider issues of equity, justice, and fairness arise with respect to mitigation and adaptation;

Many areas of climate policy-making involve value judgements and ethical considerations;

Climate policy intersects with other societal goals creating the possibility of co-benefits or adverse side-effects.
These intersections, if well-managed, can strengthen the basis for undertaking climate action: (e.g., societal goals of human health, food security, biodiversity, local environmental quality, energy access, livelihoods, and equitable sustainable development)

Risks & uncertainties, and how they are perceived by individuals and organization.